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LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Relationships Between Night Breezes and Blister Rust Spread on Lake-States White Pines[1]

This paper presents preliminary information on a new phase of research into the role of climate and microclimate in white pine blister rust spread. It is an amalgamation of several lines of evidence rather than a new field of study. A number of bits of evidence, such as spore transport by the countercurrents of drainage winds into swamps, forest edge breezes, and lake breezes, all hint at a larger scale picture in which certain characteristic night breezes seem to be functioning as carriers of spores from ribes leaves to white pines.

There is a body of available literature on how spore clouds disperse in winds and spread plant diseases. Such studies are mainly theoretical and are based on mathematical dispersion equations and balances between turbulent lifting and sedimentation, according to Stokes' Law of Rate of Fall. These theories, which emphasize turbulent lifting (Hirst 1959) and gravitational fall (Schrödter 1960) as the important parts of dissemination, apply more properly to day-released spores. Under daytime conditions, wind paths are not considered important in transmitting spores unless full account is taken of turbulent diffusion (Schrödter 1960).

Turbulent diffusion, however, does not disperse night-released spores to a great extent. I feel that tracing the paths of the spores themselves and the breezes that carry them is a realistic approach to the problems associated with spread of a disease whose spores are released under stable conditions.

Blister rust sporidia are released from the ribes plant at night, with a peak at 1 a.m. They are spherical and 10 to 12 microns in diameter. According to Potts (1946, 1959) in his insecticide aerosol work, this size is the lower limit of what can settle out in the air. Droplets less than 10 microns will not settle; those larger can although only those more than 25 microns will consistently settle. My own observations of blister rust spread indicate that sometimes sporidia settle; generally they do not.

A number of areas were discovered in which the pine hosts and the ribes hosts were not on the same soil types. These areas were used to observe historical rust spread. They were in sandy glaciated parts of the northern Lake States where pines grow on the sandy uplands, and the ribes are found in the organic soils in swampy potholes and lake margins. Since the white pine produces one whorl of branches each year, it was possible to date infections and see a complete history of when and where they occurred during the previous 20 years. These data permitted us to trace the paths of infection from particular ribes patches through nearby ribes-free pine stands.

Much of our evidence on the role of night breezes in the spread of rust is based on the correlation of these histories of infection and the breezes occurring in weather suitable for sporidial production, sporidial transport, and pine infection.

Swamp Edges

Observations of colored grenade smoke in cool northern Wisconsin highlands showed that thermal air currents, under temperature-inversion conditions, could explain rust distribution in nearby white pine.

Figure 1 illustrates this movement. The air on the slope is cooled by outward radiation and drains downslope into the swamp under the spruce-fir crowns. Since the tree crowns prevent outward radiation, the air is not cooled further. It is then lifted into the crowns as fresh supplies of even cooler air drain down from the open slope and slide under the warmer air beneath the trees. The reverse flow of air moves along the top of a shallow inversion layer from the crowns of trees in the swamp to the upland slope.

In our tests, smoke released in ribes-infested swamp edges under border tree crowns moved through the crowns and along the same circular path as smoke released on the open slope. Thus, these circulations could move spores from swamp ribes to hilltop pines.

In addition to the smoke patterns, there is evidence from the historical rust-spread data recorded on the pine trees. Swamp edges in northeastern Wisconsin generally have more blister rust present on the upland

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FIGURE 1. — Smoke movements show air currents that match the spread of white pine blister rust from swamp ribes to upland white pines in northeastern Wisconsin.

pines away from the ribes than on pines near the ribes-infested swamp. The pattern is: little or no rust in small trees near the swamp, top rust in tall trees near the swamp, lower crown rust at a greater distance, and low rust on trees (including small ones) at the divide between swamps. Thus, rust-infection patterns indicated that spores moved in paths similar to those of smoke in the normal air circulation patterns found under inversion conditions.

Mountain Winds

Lloyd and others (1959), using silver-iodide tracers, traced winds down a mountain slope and onto a lake. At that point, an updraft elevated the tracers to a wind aloft that was blowing through a mountain pass and down the slope on the other side of the mountain. This movement matched the spread of rust from one side of the mountain range to the other.

Forest Edges

A number of tests, the first of which was reported at the New Haven Agricultural Meteorological Meetings in 1958, have shown that a specific air current relationship exists at the edge of a woods. Air flows close to the ground from the open area into the woods, up under the crowns in an updraft, and then back out into the open area. Rust spores travel in a warm backflow layer which extends from under the tops of the crowns out into the open, where a downdraft may eventually bring them down (Van Arsdel 1958).

For example, in a field in northeastern Minnesota, at the top of the divide from where the slope runs down to Lake Superior, we planted white pine trees in an open field surrounded by 35- to 45-foot aspens. These trees did not develop equal numbers of blister rust cankers. Those in the center of the field had 50 times as much rust as those near the edges.

A long area of heavy rust concentration in the center of the field paralleled the edges of the taller forests on two sides of the plot. Yet, alternate hosts were distributed throughout the field and the surrounding woods. The rust distribution in this field was just exactly what would be expected if the spores were all carried by air currents in two opposing cells going into the surrounding hardwoods (away from the center of the field), then up through the hardwoods and back to the center of the field where a downdraft occurred.

While we have not yet traced the air currents around this field with smoke, as we have done in some other areas, I feel that our eventual tests will show nighttime air currents matching the circulation cells I have hypothesized from the distribution of rust in the field.

Lake Breezes

We have stronger evidence that breezes developed near Great Lakes shorelines carry blister rust fungus spores. These 2-m.p.h. breezes develop as a result of the difference between the air temperatures over

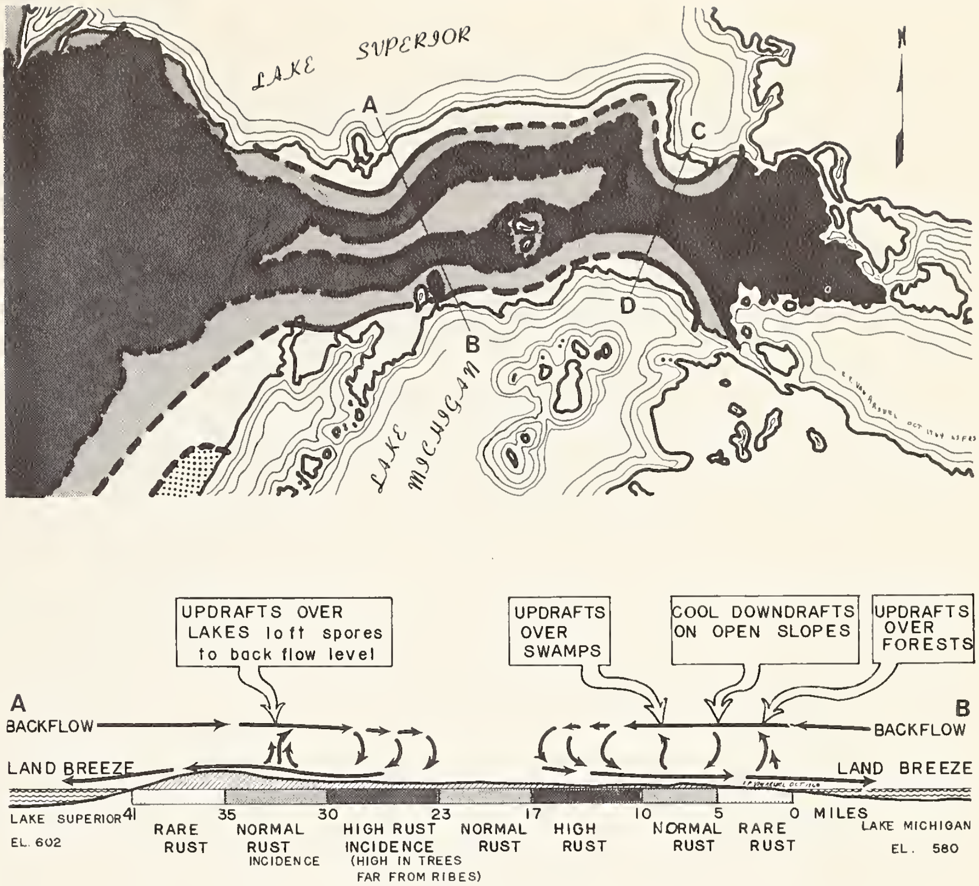

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FIGURE 2.—Map (top) shows areas of types of blister rust distribution. Diagram (bottom) shows night land breezes and backflows that give this spread pattern. Shadings for rust spread zones are the same in the chart and map.

the land and the water. To test this theory, we conducted a study in the eastern part of Michigan's Upper Peninsula on the 40-mile-wide strip of land between Lakes Michigan and Superior (fig. 2). The following is a brief description of what we learned.

As the land gets cold at night, adjacent cooled air moves in a low, cold flow out over the warmer lake (see bottom portion of figure 2 for flow lines). Spores released on currant bushes less than 5 miles from the lake are usually carried out over the water by this breeze; thus pines near the lakes are seldom infected. Above this cold flow a reverse flow carries the warmer lake air back over the land. Local warm spots above the land area, such as those over swamps, forests, and small lakes, loft some spores to this backflow level. They ride the backflow to a strip 5 to 10 miles from the lake, where they are carried down by a downdraft. These spores infect pines both high in the crowns and as much as 5 miles from the nearest currant bushes.

While we have not traced the spores all the way along this path, we have watched the lake breeze and counter currents carry smoke and balloons along the way. We know the spores have 5 hours to move (before light kills them) in a 2-m.p.h. breeze, so they can go 10 miles. This movement just fits the pattern of rust infections that has occurred on the pines in the past 20 years.

Breezes around smaller lakes seem to carry spores in similar patterns. The principal evidence of this is the many cankers found in the tops of a belt of white pine trees at some distance from many of the lakes. Pines closer to these lakes and at a greater distance than this belt do not have many cankers in their tops. The distance of this heavily infected belt varies with the topography and is usually just short of the first high ridge back from the lake. The flows seem to be generated by downslope winds, which are reinforced by the temperature difference between the land and water. Downslope winds are carried out over the lake. Near the center of the lake they ascend to a higher level and return shoreward until they reach the belt near the top of the hill where pines are infected and the major downflow begins.

Land Divides and the Lake Superior Basin

In a variety of directions from Lake Superior's shores, surveys of blister rust infections show a greater amount of rust in the tops of trees at some distance from the lake than near the shore. On the flat land of eastern Upper Michigan the greater rust occurs in a zone about 12 miles from the lake. A great deal of high-crown rust is concentrated just north of the divide between the St. Croix River Valley and Lake Superior (southeast of Superior, Wis.). South of this

divide, high-crown rust is rare or absent. Away from the north shore of Lake Superior and near the Laurentian Divide, there is a similar but less sharply defined distribution of much heavier rust; on the northwest side of the Divide there is less rust. The zone of high rust around the Lake Superior basin seems to indicate that rust sporidia released at night are being moved principally by nighttime circulations set up by downslope winds reinforced by lake breezes, and their countercurrents.

Other rust concentrations that occur west of Lake Superior along the Laurentian Divide through Itasca Park between the Mississippi Valley and Hudson Bay drainages suggest an interesting possibility: perhaps large-scale valley winds can influence rust distribution in somewhat the same manner as the lake breezes, although lakes are not involved.

Discussion

These lines of presumptive evidence, put together, suggest that there are important controlling breezes that spread the rust. Although we do not have the proofs, this mass of evidence indicates an area of productive research that we intend to follow vigorously. In future studies we plan to use silver-iodide tracers, wind tunnels, and tagged spores to complete the picture. Eventually, basic information on night winds and their relationships to rust spread may be applied in a practical way to help control this serious forest disease.

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Literature Cited

Hirst, J. M.
1959. Spore liberation and dispersal. *In* Plant Pathology, Problems and Progress 1908-1958, edited by C. S. Holton *et al.*, pp. 529-538. Madison: Univ. of Wis.

Lloyd, Merle G., O'Dell, Clyde A., and Wells, H. G.
1959. A study of spore dispersion by use of silver-iodide particles. Am. Met. Soc. Bul. 40: 305-309, illus.

Potts, S. F.
1946. Particle size of insecticides and its relation to application, distribution, and deposit. Jour. Econ. Ent. 39: 716-720.

Potts, S. F.
1959. Equipment for pest and disease control. Unasylva 13: 89-101; 138-154.

Schrödter, Harold.
1960. Dispersal by air and water—the flight and landing. *In* Plant Pathology, An advanced Treatise; vol. 3, edited by J. G. Horsfall and A. E. Dimond. pp. 169-227. New York: Acad. Press.

Van Arsdel, E. P.
1958. Smoke movement clarifies spread of blister rust from ribes to distant white pines (Abstr.) Am. Met. Soc. Bul. 39: 442-443.

Van Arsdel, E. P.
1964. Night breeze—blister-rust-spread relationships on Lake States white pines (Abstr.) Am. Met. Soc. Bul. 45: 404.

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